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**DATA PROCESSING APPARATUS, IMAGE PROCESSING  
APPARATUS, AND METHOD THEREFOR**

**BACKGROUND OF THE INVENTION**

**Technical Field**

[0001] The present invention relates to a data processing apparatus, an image processing apparatus and a method therefor, for embedding additional information, such as copyright information, in object data, such as image data or audio data. More particularly, the present invention is directed to a data processing apparatus, an image processing apparatus and a method therefor, for appropriately selecting from a plurality of candidate data sets, in accordance with object data contents, optimal watermark data that while ordinarily indiscernible can be easily detected, and for embedding the watermark data in the object data.

**Prior Art**

[0002] In International Publication No. WO 97/49235, for example, a system is disclosed for employing pixel block coding (PBC) to embed copyright information (also generally referred to, hereinafter, as verification data) in object data, such as image data, so that it is not visually discernible (the system for embedding verification data in content data so that it is not visually discernible is also, hereinafter, called an "electronic watermarking system).

**[0003]** In International Publication No. WO 98/116928 a method is disclosed for employing the electronic watermarking system disclosed in document 1 to inhibit the alteration of image data and to effectively protect literary materials.

**[0004]** In Japanese Unexamined Patent Publication No. Hei 10-164549, an improvement, to the electronic watermarking method in document 1, is disclosed for verifying indivisible embedded watermark data in order to detect the alteration of image data. In addition to these documents, an invention concerning the electronic watermarking system is disclosed in Japanese Unexamined Patent Publications Nos. Hei 09-151747, Hei 10-83310, Hei 10-106149, Hei 10-161933, Hei 10-164349, Hei 10-285562, Hei 10-334272, Hei 10-240626 and Hei 10-240129, and USP 5,315,448 (Japanese Patent No. Hei 8-507912), USP 5,745,604, USP 5,768,426, USP 5,850,481 and USP 5,832,119.

**[0005]** However, excluding one part of these documents, a method is not disclosed for optimizing watermark data in accordance with the contents of object data, e.g., the quality of the images provided by image data, and for embedding the optimized watermark data.

**[0006]** Further, while one part of these documents carries a description concerning a method, in accordance with the contents of an image, for changing watermark data that is to be embedded, the methods disclosed in the documents are less compatible with the properties of the data that are to be embedded, and thus, the watermark data can not be satisfactorily optimized.

[0007] To resolve the conventional problem, it is highly desirable to provide a data processing apparatus, and a method therefor, for optimizing watermark data that indicate the presence of additional information, such as copyright information, in accordance with the contents of object data, and for embedding the optimized watermark data.

[0008] It is further highly desirable to provide an image processing apparatus, and a method therefor, for optimizing watermark data in accordance with the quality of image data, such as the property of an object, so that watermark data that is less noticeable but is easily detectable can be employed to perform embedding.

### **SUMMARY OF THE INVENTION**

[0009] To achieve the above objects, the present invention is directed to a data processing apparatus selecting one of a plurality of candidate data corresponding to watermark data embedded into object data to embed the selected candidate data as the watermark data, comprises: a variation indication data generation means for generating a plurality of variation indication data indicating variation between the object data and each of the object data obtained by embedding each of the plurality of the candidate data; a detectability indication data generation means for generating a plurality of detectability indication data each indicating how easily each of the plurality of candidate data being detected; a watermark data selection means for selecting one of the candidate data based on the plurality of variation indication data and the plurality of detectability indication

data; and a data embedding means for embedding the selected candidate data into the object data as the watermark data.

**[0010]** The present invention is further directed to an image processing apparatus selecting one of a plurality of candidate data corresponding to watermark data embedded into object image data to embed the selected candidate data into the object image data as the watermark data, comprising: a variation indication data generation means for generating a plurality of variation indication data indicating variation between the image data and each of the image data obtained by embedding each of the plurality of the candidate data; a detectability indication data generation means for generating detectability indication data each indicating how easily each of zero or more candidate data being detected; a candidate data selection means, for employing the detectability indication data to select one of the candidate data that corresponds to variation indication data for variations that are smaller than a predetermined reference; and a data embedding means for embedding the selected candidate data as the watermark data in the image data.

**[0011]** Preferably, the detectability indication data generation means generates detectability indication data indicating the detectability of the candidate data corresponding to the variation indication data indicating variations smaller than the predetermined reference.

**[0012]** Also, when no candidate data corresponding to the variation indication data for variations smaller than the predetermined reference exists, preferably, the

candidate data selection means selects predetermined supplement data, instead of the candidate data.

**[0013]** In addition, each of the object image data is each of a plurality of image blocks obtained by dividing one image data set, and each of the watermark data corresponding to each of the object image data is each of one or more types of constituent data constituting additional information that is added to the object image data. The image processing apparatus further comprises: a watermark data correspondence means for corresponding the constituent data constituting the additional information data with the plurality of image blocks, as the watermark data; and a candidate data generation means for generating the plurality of candidate data corresponding to the constituent data corresponded with the plurality of image block.

**[0014]** Preferably, the watermark data correspondence means accepts predetermined key data to correspond the constituent data of the additional information data with the plurality of image blocks based on the predetermined key data.

**[0015]** Preferably, the candidate data generation means generates, as the plurality of candidate data, a plurality of additional patterns employing the same configuration as the object image data to be added to the object image data.

**[0016]** Also, the candidate data generation means preferably generates the plurality of additional patterns by multiplying a plurality of predetermined coefficients

with basic patterns corresponding to the constituent data corresponded with the image blocks.

**[0017]** In addition, the detectability indication data generation means preferably calculates the detectability indication data representing a correlation between the additional patterns and the basic patterns. The candidate data selection means selects, from among the additional patterns, a pattern corresponding to detectability indication data representing the highest correlation. The image processing apparatus further comprises: a watermark data detection means for detecting the watermark data embedded into the image block, based on the correlation of the basic patterns and an image block into which the selected additional pattern embedded.

**[0018]** Preferably, the watermark data correspondence means sorts the plurality of image blocks into one or more of groups, each of which including one or more of the image blocks to correspond the constituent data with the image blocks that are included in the groups.

**[0019]** Also, the variation indication data generation means preferably calculates each of differences between each of entropy values for the object image data and each of entropy values for the object image data obtained by embedding each of the plurality of candidate data as the variation indication data.

**[0020]** In addition, the detectability indication data generation means preferably generates the detectability indication data for the respective candidate data corresponding to the variation indication data with their values within a predetermined range.

**[0021]** The present invention is still further directed to a data processing method, for selecting one of a plurality of candidate data corresponding to watermark data embedded into object data for embedding the selected candidate data as the watermark data, comprising: a variation indication data generation step of generating a plurality of variation indication data indicating variation between the object data and each of the object data obtained by embedding each of the plurality of the candidate data; a detectability indication data generation step of generating a plurality of detectability indication data each indicating how easily each of the plurality of candidate data being detected; a watermark data selection step of selecting one of the candidate data based on the plurality of variation indication data and the plurality of detectability indication data; and a data embedding step of embedding the selected candidate data into the object data as the watermark data.

**[0022]** Even further, the present invention is directed to an image processing method, for selecting one of a plurality of candidate data corresponding to watermark data embedded into object image data for embedding the selected candidate data into the object image data as the watermark data, comprising: a variation indication data generation step of generating a plurality of variation indication data indicating variation between the image data and each of the image data obtained by embedding each of the plurality of the candidate data; a detectability indication data generation step of

generating detectability indication data each indicating how easily each of zero or more candidate data being detected; a candidate data selection step of employing the detectability indication data to select one of the candidate data that corresponds to variation indication data for variations that are smaller than a predetermined reference; and a data embedding step of embedding the selected candidate data as the watermark data in the image data.

**[0023]** Still even further, the present invention provides a first storage medium on which a computer-readable program selecting one of a plurality of candidate data corresponding to watermark data embedded into object data to embed the selected candidate data as the watermark data, the computer-readable program permitting a computer to perform: a variation indication data generation step of generating a plurality of variation indication data indicating variation between the object data and each of the object data obtained by embedding each of the plurality of the candidate data; a detectability indication data generation step of generating a plurality of detectability indication data each indicating how easily each of the plurality of candidate data being detected; a watermark data selection step of selecting one of the candidate data based on the plurality of variation indication data and the plurality of detectability indication data; and a data embedding step of embedding the selected candidate data into the object data as the watermark data.

**[0024]** The present invention further provides, a second storage medium on which a computer-readable program selecting one of a plurality of candidate data corresponding to watermark data embedded into object image data to embed the selected candidate data

into the object image data as the watermark data, the computer-readable program permitting a computer to perform: a variation indication data generation step of generating a plurality of variation indication data indicating variation between the image data and each of the image data obtained by embedding each of the plurality of the candidate data; a detectability indication data generation step of generating detectability indication data each indicating how easily each of zero or more candidate data being detected; a candidate data selection step of employing the detectability indication data to select one of the candidate data that corresponds to variation indication data for variations that are smaller than a predetermined reference; and a data embedding step of embedding the selected candidate data as the watermark data in the image data.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0025] Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0026] Fig. 1 is a diagram showing the arrangement of an image processing system that carries out an image processing method according to the present invention.

[0027] Fig. 2 is a diagram showing the hardware arrangement (a computer) for a watermarking unit, a detector and a server in Fig. 1.

[0028] Fig. 3 is a diagram showing the structure of a watermark program that is executed by the watermarking unit in Fig. 1 in order to perform a watermark data embedding process in accordance with the present invention.

[0029] Figs. 4A and 4B are specific diagrams showing the image division process performed by an image divider in Fig. 3, with Fig. 4A showing the image blocks  $I_{ij}$  obtained by the image division, and Fig. 4B showing the structure of each image block  $I_{ij}$ .

[0030] Fig. 5 is a diagram showing the structure of a basic pattern processor in Fig. 3.

[0031] Fig. 6 is a diagram showing the grouping of the image blocks  $I_{ij}$  by a grouping unit in Fig. 5.

[0032] Fig. 7 is a diagram showing a method used by an adjusted basic pattern calculator in Fig. 3 to generate adjusted basic patterns  $P'^{hij1}$  to  $P'^{hijn}$ .

[0033] Fig. 8 is a diagram showing the arrangement of a watermark pattern generator in Fig. 3.

[0034] Fig. 9 is a diagram showing a method whereby a selector in Fig. 8 selects, from adjusted basic patterns  $P'^{hij1}$  to  $P'^{hijn}$ , the "l" adjusted basic patterns  $P''^{hij1n}$  to  $P''^{hil}$  that evidence little variation, even when added to the image block  $I_{ij}$ .

[0035] Fig. 10 is a diagram showing the structure of a detection program that is executed by the detector in Fig. 1 to perform a watermark data detection process

according to the present invention.

[0036] Fig. 11 is a flowchart (S20) showing the processing performed for the watermark program in Fig. 3.

[0037] Fig. 12 is a flowchart (S40) showing the processing performed for the watermark data detection program in Fig. 10.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION**

[0038] An image processing apparatus according to the present invention (also referred to, hereinafter, as this image processing apparatus) is the data processing apparatus for this invention, and is especially employed for the process for embedding watermark data in image data. To aid in the understanding of the invention, the image processing apparatus will be described by using specific examples wherein, to the extent possible, the same reference numerals are used as are employed in the preferred embodiment. The technical scope of the invention, however, is not limited to the specific examples.

[0039] This image processing apparatus divides input image data  $V_{in}$ , consisting of  $H$  pixels and  $W$  pixels, into a plurality of image blocks  $l_{ij}$ , each composed of  $w_b \times h_b$  (e.g.,  $8 \times 8$ ) pixels, and employs these blocks as object data for the performance of the embedding process (the object data are referred to, hereinafter, as image blocks  $l_{ij}$ ).

**[0040]** Furthermore, based on key data Key, which has an arbitrary data length, the image processing apparatus sorts the obtained image blocks Iij into groups S1 to Sg, which correspond respectively to g bits w1 to wg, constituting watermark data W having an arbitrary data length that represents additional information, such as copyright information.

**[0041]** Preferably, the image blocks Iij that are included in these groups Sh ( $1 \leq h \leq g$ ) are evenly distributed throughout the image data Vin, and do not overlap the other image blocks Iij that are included in the other group Sx ( $h \neq x$ ), while the same number of image blocks Iij as are included in the other group Sx, which belongs to the groups Sh.

**[0042]** The image processing apparatus employs the key data Key to correspond individual bits wh, of the watermark data W representing such additional information as copyright information, with two basic patterns Pha and Phb of m ( $m \geq 2$ ) types of basic patterns P1 to Pm that have the same structure as the image blocks Iij but have different contents.

**[0043]** The two basic patterns Pha and Phb ( $Pha \neq Phb$ ) correspond to the values (1, 0) of the bits wh of the watermark data W, and in accordance with the value of the bit wh, one of the basic patterns Pha and Phb is corresponded with the individual bits wh of the watermark data W (see the preferred embodiment for the detailed correspondence).

**[0044]** Further, the basic patterns Pha and Phb that are corresponded with the bits wh may or may not overlap patterns Pxa and Pxb, which are corresponded with the other

bits  $w_x$ ; however, generally, it is preferable that the basic patterns  $Ph_a$  and  $Ph_b$  be selected so that they do not overlap the others.

**[0045]** The image block  $I_{ij}$ , which is corresponded with one of the bits  $w_h$ , may or may not overlap an image block  $I_{ij}'$ , which is corresponded with another bit  $w_h'$ .

**[0046]** This image processing apparatus corresponds the bits  $w_h$ , of the watermark data  $W$ , with which the basic patterns  $Ph$  are corresponded, with the groups  $Sh$  obtained above.

**[0047]** As a result, based on the key data  $Key$ , the same pattern  $Ph_{ij}$  (the selected basic pattern) and the bits  $w_h$  of the watermark data  $W$  are corresponded for all the image blocks  $I_{ij}$  included in the group  $Sh$ , and corresponded with each image block  $I_{ij}$ , are one bit  $W_h$  and one type of basic pattern (the selected basic pattern in this embodiment)  $Ph_{ij}$ .

**[0048]** Next, the image processing apparatus of this invention performs a predetermined process, e.g., an orthogonal transformation (DFT is hereinafter used as an example), for the image blocks  $I_{ij}$ , and generates DFT transformation coefficients  $I'_{ij}$  (also referred to, hereinafter, simply as image blocks  $I'_{ij}$ ) for the image blocks  $I_{ij}$ .

**[0049]** Furthermore, the image processing apparatus adds the square of the real number and the square of the imaginary number of each element in each image block  $I'_{ij}$ , and obtains a square root  $I''_{ij}$  (referred to, hereinafter, as a power element  $I''_{ij}$  or an image block  $I''_{ij}$ ).

**[0050]** In the following explanation, the DFT is employed as the transformation; however, as a modification, another transformation method, such as a DCT (discrete cosine transformation) or a wavelet transformation, may be employed.

**[0051]** The image processing apparatus multiplies each of the DFT coefficients  $P'_{ij}$  (also referred to, hereinafter, as basic patterns  $P'_{ij}$ ) of the basic patterns  $P_{ij}$  by, for example, the identical elements of  $n$  types of coefficients (adjustment coefficients)  $C_1$  to  $C_n$ , which have the same structure as the image blocks  $I_{ij}$  and each element of which has a value of 0 to 1. Thus,  $n$  types of candidate data (adjustment basic patterns in this embodiment)  $P''_{hij1}$  to  $P''_{hijn}$  are obtained. The image processing apparatus performs the same process as is performed for the image blocks  $I'_{ij}$  for the  $n$  types of candidate data  $P''_{hij1}$  to  $P''_{hijn}$ , and obtains the power elements  $P'''_{hij1}$  to  $P'''_{hijn}$  (also referred to, hereinafter, as candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$ ).

**[0052]** The image processing apparatus of this invention calculates the entropy for  $[e(I''_{ij}+P''_{hij1})$  to  $e(I''_{ij}+P''_{hijn})]$  for values  $(I''_{ij}+P''_{hij1})$  to  $(I''_{ij}+P''_{hijn})$  obtained by adding the image blocks  $I''_{ij}$  and candidate data  $P''_{hij1}$  to  $P''_{hijn}$ . Then, the image processing apparatus calculates the absolute values of the differences between the calculated entropy values and the entropy  $e(I'_{ij})$  for the image blocks  $I'_{ij}$ , and regards them as variation indication data sets (comparison result data sets)  $R_1$  to  $R_n$ .

**[0053]** The image processing apparatus employs as a reference a predetermined threshold value  $e$ , extracted from the candidate data sets  $P''_{hij1}$  to  $P''_{hijn}$ , and selects candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$ , which correspond to variation indication data sets

R1 to Rl that hold a value equal to or smaller than the threshold value e (it should be noted that  $0 \leq l \leq n$ ; and when  $l = 0$ , there is no variation indication data equal to or smaller than the threshold value e).

**[0054]** The variation indication data are not necessarily calculated using the power elements of the DFT coefficients, and may be calculated using other elements, such as real number elements of the DFT coefficients. Furthermore, entropy need not always be used to calculate the variation values (of indiscernibility) when the candidate data are embedded in an image block, and another appropriate calculation method may be employed.

**[0055]** As is described above, the correspondence of the image blocks  $I_{ij}$  and the basic patterns  $P_{hij}$  is uniquely determined by the key data Key, the sum (referred to, hereinafter, as an inner product) is acquired for the products obtained by multiplying the individual elements of each image block  $I_{ij}$ , in which the watermark data are embedded, and the individual elements of each basic pattern  $P_{hij}$ , and the correlation of these inner products is examined to detect the watermark data. Therefore, to embed watermark data by adding one of the candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$  to the DFT coefficients  $I'_{ij}$  of the image blocks  $I_{ij}$ , one of the candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$  that is most nearly correlated with the basic pattern  $P'_{hij}$  should be employed to easily detect the watermark data.

**[0056]** The image processing apparatus calculates the inner products (detection capability data in this embodiment)  $D1$  to  $Dn$  for the basic pattern  $P'_{hij}$  and the candidate

data sets  $P''_{hij1}$  to  $P''_{hijn}$ , and selects the candidate data set corresponding to the largest inner product as the final candidate data set (an embedding pattern in this embodiment)  $P'_{ij}$  for the image block  $I_{ij}$ .

[0057] Further, the image processing apparatus embeds the watermark data by adding identical elements in the image block  $I'_{ij}$  and in the selected final candidate data  $P'_{ij}$ , and generates the resultant image data  $V_w$ .

[0058] In this example, the correlation between the basic pattern and the candidate data is employed as the scale for detectability. When another detection method is employed, only the method used to determine the detectability of the candidate data must be changed in accordance with the pertinent detection method.

[0059] When there are no candidate data that provide variation indication data that are equal to or smaller, for example, than the predetermined threshold value  $e$ , a random pattern (supplemental pattern)  $P_s$ , which is prepared in advance, is selected as the final candidate data  $P'_{ij}$  and is added to the image block  $I'_{ij}$ , and the resultant data are embedded.

[0060] The processing for handling the image data has been employed as an example; however, it is apparent that the image processing apparatus of this invention can be appropriately modified for the processing for other data.

**[0061]** An explanation will now be given, while referring to the above described example, for the relationship of the individual components of the image processing apparatus of the invention and the components shown in the preferred embodiment, and the operation of the individual components.

**[0062]** The watermark data correspondence means corresponds to an image divider 200 and a basic pattern processor 22 in the preferred embodiment.

**[0063]** The watermark data correspondence means accepts the key data Key that are used for embedding and detecting watermark data W, and the watermark data W that represent additional information, such as copyright information. Based on the key data Key and the watermark data W, the watermark data correspondence means uniquely corresponds, with each of the image blocks I<sub>ij</sub>, one of the bits w<sub>h</sub> that constitute the watermark data W and the basic pattern (selected basic pattern) P<sub>haij</sub> or P<sub>hbij</sub>, which corresponds to the bit w<sub>h</sub> and which has a bit value of 0 or 1.

**[0064]** The candidate data generation means corresponds to a basic pattern adjustment unit 26 in the preferred embodiment. The candidate data generation means multiplies the elements of the basic pattern P'<sub>hij</sub>, which the watermark data correspondence means corresponded with the image block I<sub>ij</sub>, by the identical elements of a plurality of coefficients (adjustment coefficients) C<sub>1</sub> to C<sub>n</sub>, and generates a plurality of candidate sets (adjustment basic patterns) P'<sub>hij1</sub> to P'<sub>hijn</sub>.

**[0065]** In the image processing apparatus of the invention, the variation indication data generation means corresponds to entropy calculators 280 and 284, and an adder 282 and a comparator 286 in accordance with the preferred embodiment. For the variation indication data, the entropy of the image block  $I''_{ij}$  and the entropy of the values obtained by adding the image block  $I''_{ij}$  and each of the candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$  are calculated. The absolute values of the differences provided by entropy are obtained for each of the variation indication data sets (comparison data sets)  $R1$  to  $Rn$  that represent the variations due to the embedding of the candidate data.

**[0066]** As the entropy variations become smaller, accordingly the variations in the image block due to the embedding of the candidate data are also reduced. And when the values of the variation indication data are small, the candidate data are indiscernible when they are embedded in an image block.

**[0067]** The detectability indication data generation means corresponds to a detectability calculator 292 in the preferred embodiment. The detectability indication data generation means calculates the accumulated addition values (referred to, hereinafter, as inner products) obtained by multiplying the elements of the basic pattern  $P'_{hij}$ , which is corresponded with the image block  $I_{ij}$ , and the identical elements of the candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$ , which provide the variation indication data having values equal to or smaller than the predetermined threshold value  $e$ . These inner products are regarded as detectability indication data sets  $D1$  to  $Dn$ .

**[0068]** As is described above, the watermark data that is embedded in the individual image blocks is detected by obtaining the correlation of the image block  $I_{ij}$  and each of the basic patterns  $P_{ha}$  and  $P_{hb}$ , which correspond to the watermark data wh assigned for the individual image blocks.

**[0069]** Therefore, it is found that of the candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$ , the candidate data that provides the basic pattern  $P'_{hij}$  having the maximum inner product can be detected most easily.

**[0070]** The watermark data selection means corresponds to selectors 290 and 296 in the preferred embodiment. The watermark data selection means compares the variation indication data sets  $R1$  to  $Rn$  with the threshold value  $e$ , and selects the candidate data that correspond to indication data that are equal to or smaller than the threshold value.

**[0071]** The detectability indication data generation means calculates the detectability indication data sets  $D1$  to  $Dn$  for the individual candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$  selected by the watermark data selection means.

**[0072]** Further, as the final candidate data (watermark pattern)  $P'_{ij}$  for the image block  $I_{ij}$ , the watermark data selection means selects one of the candidate data sets  $P'''_{hij1}$  to  $P'''_{hijn}$  that corresponds to the maximum detectability indication data.

**[0073]** When in this manner the watermark data selection means selects the candidate data at two stages, the calculations required of the detectability indication data generation means can be reduced.

**[0074]** When the calculations need not be taken into account, both the variation indication data generation means and the detectability indication data generation means can calculate the variation indication data and the detectability indication data for all the candidate data sets  $P'_{hij1}$  to  $P'_{hijn}$ , and the watermark data selection means can simultaneously employ these two data sets to select the candidate data  $P'_{ij}$ .

**[0075]** The data embedding means corresponds to a pattern embedding unit 204 in the preferred embodiment.

**[0076]** The data embedding unit embeds the selected final candidate data (watermark pattern)  $P'_{ij}$  in the image block  $I_{ij}$  by adding the coefficient of the final candidate data  $P'_{ij}$  to the identical coefficient of the image block  $I'_{ij}$ .

**[0077]** The data detection means corresponds to a watermark data detection program 40 in the preferred embodiment.

**[0078]** Based on the key data Key, for example, the data detection means corresponds the image blocks  $I'_{ij}+P'_{ij}$  with the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$ , which respectively correspond to the bit values 0 and 1.

[0079] Further, the data detection means obtains the correlations between the image block  $I_{ij}$  and the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$ , and employs the correlations to detect the individual bits of the watermark data  $W$ .

[0080] Fig. 1 is a diagram showing the configuration of an image processing system 1 that carries out an image processing method according to the present invention.

[0081] Fig. 2 is a diagram showing the hardware arrangement used for a watermarking unit 2, a detector 4 and a server 12 in Fig. 1.

[0082] As is shown in Fig. 1, the image processing system 1 is so designed that the watermarking unit 2, the server 12 and the detector 4 are connected via a data transmission network, such as an ISDN network, a telephone communication network, or via a data communication network 10 such as a LAN.

[0083] As is shown in Fig. 2, the watermarking unit 2, the server 12 and the detector 4 in Fig. 1 are constituted by a computer 16.

[0084] The computer 16 comprises: a main body 160, including a CPU 162, a memory 164 and their peripheral circuits; a display device 166, such as a CRT display; an input device 168, such as a keyboard or a mouse; a communication unit 170 for exchanging data with another node across the network 10; and a storage device 172, such as a DVD drive, a floppy disk drive or a CD-ROM drive.

[0085] In other words, the computer 16 (the watermarking unit 2, the server 12 or the detector 4) employs a general computer arrangement having a communication function.

[0086] The server 12 supplies, as needed, image data  $V_{in}$ , watermark data  $W$  and key data  $Key$ , or an arbitrary combination of these data, to the watermarking unit 2 via the network 10 or via a storage medium 14, such as a DVD, a CD-ROM or a floppy disk.

[0087] Fig. 3 is a diagram showing the arrangement of a watermarking program 20, for carrying out the watermark data embedding process of this invention, that is executed by the watermarking unit 2.

[0088] The watermarking unit 2 receives the watermarking program 20 from the server 12, via the network 10 (Fig. 1), or from the storage medium 14, via the storage device 172, and executes it. Thus, the watermarking unit 2 embeds watermark data  $W$ , which represents the copyright information, in the image data  $V_{in}$  that are supplied by the server 12, via the network 10, or by the storage medium 14, and obtains watermarked image data  $V_w$  (Fig. 3) in which the watermark data are embedded.

[0089] The watermarking unit 2 transmits the obtained image data  $V_w$  to the detector 4 or to the server 12 via the network 10, or stores the image data  $V_w$  on the storage medium 14 using the storage device 172 and then supplies it to the detector 4 or the server 12.

[0090] As is shown in Fig. 3, the watermarking program 20 comprises: an image divider 200, orthogonal transformation units 202 and 24, a pattern embedding unit 204, an output unit 206, a power element calculator 208, a basic pattern processor 22, a basic pattern adjustment unit 26, and a watermark pattern generator 28.

[0091] The basic pattern adjustment unit 26 is constituted by an adjusted basic pattern calculator 262, an adjustment coefficient storage unit 260 and a power element calculator 264.

[0092] Figs. 4A and 4B are specific diagrams showing the image division process performed by the image divider 200 in Fig. 3. In Fig. 4A, image blocks  $I_{ij}$  are shown as the image division results, and in Fig. 4B, the structure of each image block (object image data)  $I_{ij}$  is shown. In Fig. 4, to simplify and clarify the explanation, the number of pixels used to constitute an image is much smaller than the number that is actually required.

[0093] Based on the structure  $(H, W)$  of image data  $V_{in}$  (one set of image data) and the structure  $(hb, wb)$  of the image blocks  $I_{ij}$ , which are designated and input by a user via the input device 168 (Fig. 2), as is shown in Fig. 4A, the image divider 200 (Fig. 3) divides the input image data  $V_{in}$ , consisting of  $H \times W$  pixels, into  $s \times t$  image blocks  $I_{11}$  to  $I_{st}$  ( $s = H/hb$ ,  $t = W/wb$ ,  $1 \leq i \leq s$ ,  $1 \leq j \leq t$ ), each of which is constituted by  $hb \times wb$  pixels, as is shown in Fig. 4B. The obtained  $s \times t$  image blocks are then output to the orthogonal transformation unit 202.

[0094] The orthogonal transformation unit 202 performs the DFT transformation shown in equation 1 for the image blocks  $I_{ij}$  that are received from the image divider 200, and outputs the obtained DFT coefficients  $I'_{ij}$  (also referred to, hereinafter, as image blocks  $I'_{ij}$ ) to the pattern embedding unit 204 and the power element calculator 208.

[0095] Equation 1

$$I'_{ij} = F(I_{ij}) \quad \dots (1)$$

[0096] wherein  $F$  denotes a Fourier transformation.

[0097] The power element calculator 208 adds together the squared power values of the real element ( $Re$ ) and the imaginary element ( $Im$ ) of each of the image blocks  $I'_{ij}$  received from the orthogonal transformation unit 202. The power element calculator 208 calculates the square root  $[(Re^2 + Im^2)^{1/2}]$  of the sum provided by the addition to obtain the power element  $I''_{ij}$  of  $hb \times wb$  (also referred to, hereinafter, as an image block  $I''_{ij}$ ), and outputs the obtained power element to the watermark pattern generator 28.

[0098] Fig. 5 is a diagram showing the structure of the basic pattern processor 22 in Fig. 3.

[0099] As is shown in Fig. 5, the basic pattern processor 22 comprises a grouping unit 220, a bit correspondence unit 222, a basic pattern storage unit 224, and a basic pattern selector 226.

**[00100]** Based on the above described image constituent data and the key data Key, which are set by a user at the input device 168 (Fig. 2) and are used to embed and detect watermark data, the basic pattern processor 22 employs these components to uniquely correspond the image blocks  $I_{ij}$  with a bit  $w_h$  (constituent data;  $1 \leq h \leq g$ ) extracted from the  $g$  ( $g$  is an arbitrary integer) bits  $w_1$  to  $w_g$  that constitute the watermark data  $w$  indicating additional information, such as copyright information for the image data  $V_{in}$ , and with the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$  (e.g., the bit  $w_h$ ) that are included in the basic patterns  $P_1$  to  $P_m$  ( $m \geq 2$ ) and that correspond to the values 0 and 1 of the bit  $w_h$ .

**[00101]** As is shown in Fig. 4B, the basic patterns  $P_1$  to  $P_m$  have the same  $h_b$   $w_b$  structure as has the image block  $I_{ij}$ .

**[00102]** Actually, in accordance with the value of the bit  $w_h$  that corresponds to each image block  $I_{ij}$ , one of the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$  is output by the basic pattern processor 22 as a selected basic pattern  $Ph_{ij}$  that corresponds to the image block  $I_{ij}$ .

**[00103]** Fig. 6 is a diagram showing the image blocks  $I_{ij}$  grouped using the grouping unit 220 in Fig. 5. In Fig. 6, the watermark data  $W$  are constituted by 10 bits, all the image blocks  $I_{ij}$  are included in specific groups (not all the image blocks  $I_{ij}$  need always be included in specific groups), and the structures in Figs. 4A and 4B are employed for the image data  $V_{in}$  and the image block  $I_{ij}$ .

**[00104]** As is shown in Fig. 6, based on the above image constituent data, the grouping unit 220 prepares, in the image data  $V_{in}$ , groups  $S_1$  to  $S_g$ , each of which includes the same number of image blocks  $I_{ij}$  that do not overlap each other and are distributed as evenly as possible. The grouping unit 220 then transmits the data representing the groups  $S_1$  to  $S_g$  to the bit correspondence unit 222.

**[00105]** The bit correspondence unit 222 (Fig. 5) corresponds each of the groups  $S_1$  to  $S_g$  (Fig. 6) with one of the bits  $w_1$  to  $w_g$  of the watermark data  $w$  (for the easiest example, bit  $w_h$  for  $S_h$  ( $1 \leq h \leq g$ )), and transmits the results to the basic pattern selector 226.

**[00106]** The basic pattern storage unit 224 stores  $m$  types ( $m \geq 2$ ) of basic patterns  $P_1$  to  $P_m$ , which are input by a user via the input device 168 or which are received from the storage device 172, and outputs them to the basic pattern selector 226.

**[00107]** As is shown in Fig. 4B, the basic patterns  $P_1$  to  $P_m$  are pixel patterns having different  $h_b \times w_b$  pixel structures ( $P_b \neq P_q$  ( $p \neq q$ ,  $1 \leq p, q \leq m$ )). For example, the basic patterns  $P_1$  to  $P_m$  are stored in advance in the basic pattern storage unit 224, or are generated from data held by the basic pattern storage unit 224, by using the key data  $Key$  and the watermark data  $W$ , or from data input to the basic pattern storage unit 224 by a user, via the input device 168 or the storage device 172.

**[00108]** When the types  $m$  of the basic patterns are reduced in accordance with the bit count  $g$  of the watermark data, while taking into account the detectability and the

volume of the watermark data that is processed, the performance of the image processing system 1 is enhanced.

[00109] The basic pattern selector 226 (Fig. 5) corresponds the bit  $w_h$  of the watermark data  $w$ , which was corresponded with the group  $sh$  by the bit correspondence unit 222, with the two different basic patterns  $Ph_a$  and  $Ph_b$  ( $Ph_a \neq Ph_b$ ) of the basic patterns  $P_1$  to  $P_m$  that are received from the basic pattern storage unit 224.

[00110] Furthermore, for example, when the value of the bit  $w_h$  is 0, the basic pattern selector 226 selects the basic pattern  $Ph_{ij}$ , or in another case selects the pattern  $Ph_{bij}$ , so that the same basic pattern  $Ph$  is corresponded with all the image blocks  $I_{ij}$  that are included in the group  $Sh$ .

[00111] As the selected basic pattern  $Ph_{ij}$  that is corresponded with each of the image blocks  $I_{ij}$ , the basic pattern selector 226 outputs correspondence results to the orthogonal transformation unit 24.

[00112] The orthogonal transformation unit 24 (Fig. 3) performs the DFT process shown in equation 2 for the selected basic pattern  $Ph_{ij}$  that is input by the basic pattern processor 22, and outputs the obtained DFT coefficient  $P'_{hij}$  (referred to, hereinafter, simply as a selected basic pattern  $P'_{hij}$ ) to the basic pattern adjustment unit 26 and the watermark pattern generator 28.

[00113] Equation 2

$$P'_{hij} = F(Ph_{ij}) \quad \dots (2)$$

[00114] The basic pattern adjustment unit 26 adjusts the value of the elements in the selected basic pattern  $P'_{hij}$  of each image block  $I_{ij}$ , and generates  $n$  types of adjusted basic patterns  $P'_{hij1}$  to  $P'_{hijn}$  and outputs them to the basic pattern adjustment unit 26.

[00115] In the basic pattern adjustment unit 26, the adjustment coefficient storage unit 260 stores  $n$  types of adjustment coefficients  $C1$  to  $Cn$ , which are predetermined, which are input by a user via the input device 168 (Fig. 2), or which are generated by using the key data  $Key$  and the watermark data  $W$ . The adjustment coefficients  $C1$  to  $Cn$  are then output to the adjusted basic pattern calculator 262.

[00116] The adjustment coefficients  $C1$  to  $Cn$  have the same  $hb \times wb$  structure as has the image block  $I_{ij}$  in Fig. 4B, and each element has a value of 0 to 1 (it should be noted that, in accordance with the application, the value need not fall within this range).

[00117] Fig. 7 is a diagram showing a method whereby the adjusted basic pattern calculator 262 in.

[00118] Fig. 3 generates the adjusted basic patterns  $P'_{hij1}$  to  $P'_{hijn}$ .

[00119] As is shown in equation 3, the adjusted basic pattern calculator 262 multiplies the same elements in the adjustment coefficients  $C1$  to  $Cn$  and the selected basic pattern  $P'_{hij}$  of the image block  $I_{ij}$  that is received from the orthogonal transformation unit 24, and generates the  $n$  types of adjusted basic patterns  $P'_{hij1}$  to  $P'_{hijn}$

(candidate data sets) of the hb wb structure. These n types of adjusted basic patterns  $P^{hij1}$  to  $P^{hijn}$  are output to the watermark pattern generator 28.

[00120] Equation 3

[00121] For all the elements of  $C_k$  and  $P^{hij}$ ,

$$(P^{hiju})_k = (C_u)_k P^{hiju} \quad \dots (3)$$

where  $1 \leq k \leq n$  and  $1 \leq u \leq hb \times wb$ ;  $(P^{hiju})_k$  denotes the u-th element of k-th adjusted basic pattern;  $(C_u)_k$  denotes the u-th element of the k-th adjustment coefficient; and  $P^{hiju}$  denotes the u-th element of the adjusted basic pattern.

[00122] The power element calculator 264, as well as the power element calculator 208 (Fig. 3), calculates the power elements  $P^{hij1}$  to  $P^{hijn}$  (also referred to, hereinafter, as the adjusted basic patterns  $P^{hij1}$  to  $P^{hijn}$ ) of the adjusted basic patterns  $P^{hij1}$  to  $P^{hijn}$ , and also calculates the power element  $P^{hij}$  (referred to, hereinafter, as the basic pattern  $P^{hij}$ ) using the basic pattern  $P^{hij}$  that is received from the orthogonal transformation unit 24. The obtained power elements are then output to the watermark pattern generator 28.

[00123] Fig. 8 is a diagram showing the arrangement of the watermark pattern generator 28 in Fig. 3.

[00124] As is shown in Fig. 8, the watermark pattern generator 28 comprises entropy calculators 280 and 284, an adder 282, a comparator 286, a threshold value

storage unit 288, selectors 290 and 296, a detectability calculator 292, and a supplemental pattern storage unit 294.

**[00125]** The watermark pattern generator 28 employs these components to obtain comparison result data  $R_1$  to  $R_n$  (variation indication data) that indicate the variations (the relative indiscernibility of the adjusted basic patterns) for the image block  $I^{ij}$  before and after the adjusted basic patterns  $P^{''ij1}$  to  $P^{''ijn}$  are added thereto.

**[00126]** The watermark pattern generator 28 multiplies the elements in the adjusted basic patterns  $P^{''ij1}$  to  $P^{''ijn}$ , which are determined to have less variation (are indiscernible after being embedded), and the same element of the basic pattern  $P^{ij}$  that is corresponded with the image block  $I^{ij}$ . The watermark pattern generator 28 adds the multiplication values to obtain the inner products, and obtains the detectability data sets  $D_1$  to  $D_n$  (data sets for indicating detectability) that represent the detectability of the adjusted basic patterns  $P^{''ij1}$  to  $P^{''ijn}$ .

**[00127]** Furthermore, of the adjusted basic patterns  $P^{''ij1}$  to  $P^{''ijn}$ , the watermark pattern generator 28 selects, as the adjusted basic pattern that can be detected most easily, the adjusted basic pattern that provides the highest detectability data (that is the most easily detected). Then, the watermark pattern generator 28 outputs the pattern as the final watermark pattern  $P^{ij}$  to the pattern embedding unit 204 in Fig. 3.

**[00128]** In the watermark pattern generator 28, the entropy calculator 280 calculates the entropy  $e(I''_{ij})$ , of the power element  $I''_{ij}$  of the image block  $I_{ij}$ , as shown in equation 4, and outputs it to the comparator 286.

**[00129]** Equation 4

$$e(I''_{ij}) = 1/\log(N) \times S(-\log r_u) \quad \dots (4-1)$$

$$r_u = w_u I''_{ij}[u] / S_w m I''_{ij}[m] \quad \dots (4-2)$$

where  $S$  denotes the accumulated addition value  $[(\sum)]$  within a range of  $u = 1$  to  $N$ ;  $u$  denotes the  $u$ -th element of  $I_{ij}$ ;  $N$  denotes the number of elements (32) included in  $I''_{ij}$ ; and  $w_i$  denotes a predetermined constant.

**[00130]** The adder 282 adds the image block  $I''_{ij}$  and the adjusted basic patterns  $P''_{hij1}$  to  $P''_{hijn}$ , and outputs the obtained values  $(I''_{ij} + P''_{hij1})$  to  $(I''_{ij} + P''_{hijn})$  to the entropy calculator 284.

**[00131]** The entropy calculator 284, as well as the entropy calculator 280, calculates the entropy for  $e(I''_{ij} + P''_{hij1})$  to  $e(I''_{ij} + P''_{hijn})$  for the addition values  $(I''_{ij} + P''_{hij1})$  to  $(I''_{ij} + P''_{hijn})$  that are received from the adder 282, and outputs the entropy to the comparator 286.

**[00132]** The comparator 286 calculates absolute values  $|e(I''_{ij}) - e(I''_{ij} + P''_{hij1})|$  to  $|e(I''_{ij}) - e(I''_{ij} + P''_{hijn})|$  for the differences between the entropy  $(I''_{ij})$  for the image block  $I''_{ij}$  and the entropy for  $[e(I''_{ij} + P''_{hij1})$  to  $e(I''_{ij} + P''_{hijn})]$  of the addition values  $(I''_{ij} + P''_{hij1})$  to  $(I''_{ij} + P''_{hijn})$ , which are received from the entropy calculator 280. The comparator 286 obtains the resultant comparison data sets  $R_1$  to  $R_n$ , which indicate the variations (the relative indiscernibility of the adjusted basic patterns) for an image before

and after the watermark data are embedded therein by adding. The data sets  $R_1$  to  $R_n$  are then output to the selector 290.

[00133] The threshold value storage unit 288 stores a threshold value  $e$  ( $0 \leq e$ ) that is obtained, for example, through an experiment conducted in advance, is set by a user via the input device 168 or the storage device 172 (Fig. 2), or is a threshold value  $e$  that is calculated by using the key data Key and the watermark data  $w$ . Thereafter, the threshold value  $e$  is output to the selector 290.

[00134] The threshold value  $e$  is so set that when the value of the comparison data  $R_k$  ( $1 \leq k \leq n$ ) is smaller than the threshold value  $e$ , even when the adjusted basic pattern  $P'hijk$  that is corresponded with the data  $R_k$  is added to the image block  $I'ij$  and reverse transformation is performed for the resultant image block  $I'ij$ , a normal person can not or can only faintly perceive the displayed pattern, and so that when the value of the comparison data  $R_k$  ( $1 \leq k \leq n$ ) is equal to or greater than that of the threshold value  $e$ , a normal person can perceive the adjusted pattern  $P'hijk$  that is added to the image block  $I'ij$ .

[00135] Fig. 9 is a diagram showing a method whereby the selector 290 in Fig. 8 selects one of the adjusted basic patterns  $P''hijl$  to  $P''hijn$  that has only slight variations, even when the adjusted basic patterns  $P'hijl$  to  $P'hijn$  are added to the image block  $Iij$ . It should be noted that  $0 \leq l \leq n$ , and that when  $l = 0$  there are no variation indication data that are equal to or smaller than the threshold value  $e$ .

**[00136]** The selector 290 compares the threshold value  $e$  received from the threshold value storage unit 288 with the absolute values  $|e(I''_{ij}) - e(I''_{ij} + P'''_{hij1})|$  to  $|e(I''_{ij}) - e(I''_{ij} + P'''_{hijn})|$  of the differences that are received from the comparator 286. The selector 290 then selects the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijl}$  that provides the absolute value  $|e(I''_{ij}) - e(I''_{ij} + P'''_{hijk})|$  ( $1 \leq k \leq n$ ) less than or equal to the threshold value  $e$ , i.e., the absolute value  $|e(I''_{ij}) - e(I''_{ij} + P'''_{hijk})|$  that satisfies equation 5. The selected adjusted basic pattern is thereafter output to the detectability calculator 292 and the selector 296.

**[00137]** Equation 5

$$|e(I''_{ij}) - e(I''_{ij} + P'''_{hijk})| \leq e \quad \dots (5)$$

**[00138]** When there are adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijl}$  received from the selector 290, as is shown in equation 6, the detectability calculator 292 multiplies the same elements in the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijl}$  and in the basic pattern  $P'_{hij}$ , and adds the results to obtain the product sum (inner product).

**[00139]** Equation 6

$$\begin{aligned} D_k &= (P'''_{hijk})(P'_{hij}) \\ &= S(P'''_{hijk}[u]P'_{hij}[u]) \quad \dots (6) \end{aligned}$$

where  $1 \leq k \leq l$ ;  $S$  denotes the accumulated addition values ( $\Sigma$ ) within a range of 1 to  $N$ ;  $(P'''_{hijk})_u$  denotes the  $u$ -th element of  $P'''_{hijk}$ ; and  $P'_{hij}{}_u$  denotes the  $u$ -th element of  $P'_{hij}$ .

**[00140]** Furthermore, the detectability calculator 292 outputs to the selector 296, as the detectability data sets  $D1$  to  $Dl$  that represent the detectability of the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijl}$ , the inner products obtained using equation 6.

**[00141]** When the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijl}$  input by the selector 290 are not present, the detectability calculator 292 transmits a notification to that effect to the selector 296.

**[00142]** When the detectability calculator 292 notifies the selector 296 that the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijn}$  input by the selector 290 are not present, the supplemental pattern storage unit 294 receives a supplemental pattern  $P_s$ , which is output as the final watermark pattern  $P'_{ij}$ , from the input device 168 or the storage device 172 as a result of an operation performed by a user, or generates and stores the supplemental pattern  $P_s$  using the key data  $Key$  and the watermark data  $W$ . The supplemental pattern  $P_s$  is then output to the selector 296.

**[00143]** Upon the receipt of the detectability data  $D1$  to  $Dn$  from the detectability calculator 292, the selector 296 selects one of the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijn}$  that is received from the selector 290 and that corresponds to the detectability data for the maximum value, and outputs the selected basic pattern as a watermark pattern  $P'_{ij}$  to the pattern embedding unit 204 (Fig. 3). In another case, the selector 296 outputs the supplemental pattern  $P_s$  received from the supplemental pattern storage unit 294 to the pattern embedding unit 204 (Fig. 3) as the watermark pattern  $P'_{ij}$ .

**[00144]** The pattern embedding unit 204 (Fig. 3) embeds the watermark pattern by adding together the same elements in each image block  $I'_{ij}$ , received from the orthogonal transformation unit 202, and in the watermark pattern  $P'_{ij}$ , received from the watermark

pattern generator 28. The obtained image block ( $I'_{ij} + P'_{ij}$ ) is thereafter output to the output unit 206.

**[00145]** The output unit 206 performs run-length coding, for example, for the image block ( $I'_{ij} + P'_{ij}$ ) received from the pattern embedding unit 204, and forms the obtained data into a predetermined transmission format for generating embedded picture data  $V_w$ . The output unit 206 then transmits the picture data  $V_w$  to the detector 4 via the network 10, or distributes the picture data  $V_w$  to the detector 4 via the storage device 172 and the storage medium 14.

**[00146]** Fig. 10 is a diagram showing the arrangement of a detection program 40, which is executed by the detector 4 in Fig. 1, for carrying out the watermark data detection process according to the present invention.

**[00147]** The detector 4 executes the watermark data detection program 40 that is supplied to the storage device 172 via the storage medium 14, or that is supplied by the server 12 via the network 10, and implements the watermark data detection process in accordance with the present invention.

**[00148]** As is shown in Fig. 10, the watermark data detection program 40 comprises an image divider 42, a watermark pattern processor 44, an inverse orthogonal transformation unit 48, and a watermark data detector 46.

[00149] The watermark data detection program 40 employs these components to detect the watermark data  $W$  held by the picture data  $V_w$ , in which the watermark data  $W$  are embedded by the watermarking unit 2 (the watermarking process program 20).

[00150] The image divider 42 performs the inverted process for the output unit 206 of the watermarking program 20 (Fig. 3), i.e., the run-length decoding and the division process in Fig. 4A, for the image data  $V_w$  that are supplied by the watermarking unit 2 (watermarking program 20 in Fig. 3) via the network 10 or the storage medium 14. Thus, the image divider 42 obtains the image block  $I'_{ij}+P'_{ij}$  in which the watermark pattern is embedded (referred to, hereinafter, simply as the image block  $I'_{ij}+P'_{ij}$ ) and outputs it to the inverse orthogonal transformation unit 48 and the watermark data detector 46.

[00151] The inverse orthogonal transformation unit 48 performs the inverse DFT (IDFT) process for the image block  $I'_{ij}+P'_{ij}$  received from the image divider 42, and generates and stores image data  $V_{in'}$  in the storage device 172 (Fig. 2), or displays it on the display device 166.

[00152] The watermark pattern processor 44 employs key data  $Key$ , which is set by the user using the input device 168 (Fig. 2), as well as the basic pattern processor 22 in the watermarking program 20 (Fig. 3), and corresponds the image block  $I'_{ij}+P'_{ij}$  with the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$ .

**[00153]** Based on the correlation of the image block  $I'_{ij}+P'_{ij}$  and the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$ , the watermark data detector 46 detects the value of the bit  $w_h$  of the watermark data  $W$  that is embedded in the image block  $I'_{ij}+P'_{ij}$ .

**[00154]** Since the same bit is embedded in a plurality of image blocks of the watermarked image data  $V_w$ , the same bit  $w_h$  is detected in a plurality of image blocks, and a bit value obtained by a decision of the majority is regarded as the final bit  $w_h$ , so that the reliability of the detected image data  $W$  is increased.

**[00155]** The overall operation of the image processing system 1 (Fig. 1) will now be described.

**[00156]** Fig. 11 is a flowchart showing, for example, the processing (S20) of the watermarking program 20 in Fig. 3.

**[00157]** Fig. 12 is a flowchart showing the processing (S40) of the watermark data detection program 40 in Fig. 10.

**[00158]** First, the operation of the watermarking unit 2 will be described while referring to Fig. 11.

**[00159]** When the watermarking unit 2 (Fig. 1) activates the watermarking program 20 (Fig. 3), at step 200 (S200) the image divider 200 divides the image data  $V_{in}$  as is shown in Figs. 4A and 4B, and generates the image blocks  $I_{ij}$ .

**[00160]** The basic pattern processor 22 corresponds each of the image blocks  $I_{ij}$  with the selected basic pattern  $P_{hij}$ , as was explained, for example, while referring to Fig. 6.

**[00161]** The basic pattern storage unit 224 of the basic pattern processor 22 generates and stores, as needed, the basic patterns  $P_1$  to  $P_m$ .

**[00162]** The threshold value storage unit 288, of the watermark pattern generator 28, generates and stores the threshold value  $e$  as needed.

**[00163]** The supplemental pattern storage unit 294 of the watermark pattern generator 28, as needed, generates and stores the supplemental pattern  $P_s$ .

**[00164]** At step 202 (S202), the watermarking program 20 (output unit 206) determines whether the embedding process has been terminated for all the image blocks  $I_{ij}$ . When the process has been terminated, the output unit 206 generates the watermarked image data  $V_w$ , from the image block  $I'_{ij} + P'_{ij}$ , in which the watermark pattern is embedded, and distributes the image data  $V_w$  to the network 10 and the server 12.

**[00165]** At step 204 (S204), the orthogonal transformation units 202 and 24 select the next image block  $I_{ij}$  to be processed and the selected basic pattern  $P_{hij}$ .

**[00166]** At step 206 (S206), the orthogonal transformation units 202 and 24 perform DFT transformation for the image block  $I_{ij}$  and the selected basic pattern  $P_{hij}$  that are selected at step 204, and generates the image block  $I'_{ij}$  and the selected basic

pattern  $P'_{ij}$  and the power element calculators 208 and 264 generate their power elements  $I''_{ij}$ . Then, the basic pattern adjustment unit 26 generates the adjusted basic patterns  $P'_{hij1}$  to  $P'_{hijn}$ , as was explained while referring to Fig. 7.

[00167] At step 208 (S208), the entropy calculator 280, the adder 282, the entropy calculator 284 and the comparator 286 (Fig. 8), of the watermark pattern generator 28 (Fig. 3), respectively calculate the absolute values ( $R_1$  to  $R_n$ ) of the differences between the entropy values for the image block  $I''_{ij}$  and the individual values obtained by adding the image block  $I''_{ij}$  and the adjusted basic patterns  $P'_{hij1}$  to  $P'_{hijn}$ .

[00168] At step 210 (S210), the selector 290 (Fig. 8) extracts the difference (comparison data  $R_k$ ) between the entropy of the image block  $I''_{ij}$ , to be compared next, and the entropy of the  $I''_{ij}+P'_{hijk}$  ( $1 \leq k \leq n$ ), and determines whether the value of the data  $R_k$  is equal to or smaller than the threshold value  $e$  that is received from the threshold value storage unit 288. When the value of the data  $R_k$  is equal to or smaller than the threshold value  $e$ , program control advances to step 212, and when the value of the data  $R_k$  is greater than the threshold value  $e$ , program control is shifted to step 214.

[00169] At step 212 (S212), the selector 290 adds the adjusted pattern  $P'_{hijk}$ , which corresponds to the data  $R_k$ , to the process targets (candidate: adjusted basic patterns  $P'_{hij1}$  to  $P'_{hijn}$ ) of the detectability calculator 292 and the selector 296.

[00170] At step 214 (S214), the selector 290 determines whether all the  $n$  types of adjusted basic patterns  $P'_{hij1}$  to  $P'_{hijn}$  have been processed. When the process has been

completed, program control advances to step 216. But when the process has not been completed, program control returns to step 210.

**[00171]** At step 216 (S216), the detectability calculator 292 determines whether the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijn}$  (candidates) to be processed have been received from the selector 290. When the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijn}$  have been received, program control advances to step 220. But when these basic patterns have not yet been received, program control shifts to step 218.

**[00172]** At step 218 (S218), the detectability calculator 292 notifies the selector 296 that there is no processing target, and upon the receipt of this notification, the selector 296 outputs, as the watermark pattern  $P'_{ij}$ , the supplemental pattern  $P_s$  input by the supplemental pattern storage unit 294.

**[00173]** At step 220 (S220), the detectability calculator 292 calculates, as detectability data sets  $D1$  to  $Dn$ , the inner products of the selected basic pattern  $P'_{hij}$  and the individual adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijn}$  that are received from the selector 290. The selector 296 outputs, as the watermark pattern  $P'_{ij}$ , one of the adjusted basic patterns  $P'''_{hij1}$  to  $P'''_{hijn}$  that of the detectability data  $D1$  to  $Dn$  provides the maximum value.

**[00174]** At step 222 (S222), the pattern embedding unit 204 (Fig. 3) adds and embeds the watermark pattern  $P'_{ij}$ , which is received from the selector 296 (Fig. 8) of the watermark pattern generator 28, to the image block  $I'_{ij}$  that is received from the orthogonal transformation unit 202. Program control then returns to step 202.

**[00175]** As is shown in Fig. 12, when the detector 4 (Fig. 1) activates the watermark data detection program 40 (Fig. 10), at step 400 (S400) the image divider 42 divides the watermarked image data  $V_w$  that is supplied by the watermarking unit 2, via the network 10 and the server 12 or via the storage medium 14, and obtains the image blocks  $I'_{ij}+P'_{ij}$ . The watermark pattern processor 44 then employs the key data Key to correspond the image block  $I'_{ij}+P'_{ij}$  with the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$ .

**[00176]** In accordance with a user's manipulation of the input device 168 (Fig. 2), the inverse orthogonal transformation unit 48 performs the IDFT transformation for the image block  $I'_{ij}+P'_{ij}$ , and displays the result on the display device 166.

**[00177]** At step 402 (S402), the watermark data detector 46 selects the image block  $I'_{ij}+P'_{ij}$  that is to be processed next.

**[00178]** At step 404 (S404), the watermark data detector 46 obtains the correlation of the image block  $I'_{ij}+P'_{ij}$  with the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$ , and employs the correlation to determine the value of the bit  $w_h$  of the watermark data  $W$  that is embedded in the basic patterns  $Ph_{aij}$  and  $Ph_{bij}$ .

**[00179]** At step 406 (S406), the watermark data detector 46 determines whether the detection process has been completed for all the image blocks  $I'_{ij}+P'_{ij}$ . When the detection process has been completed, program control advances to step S408. But when the detection process has not been uncompleted, program control returns to step 402.

**[00180]** At step 408 (S408), the watermark data detector 46 examines the validity of the majority of the individual bits wh of the detected watermark data W. The watermark data detector 46 then combines the detected bits wh and outputs them as the watermark data W.

**[00181]** As is described above, the data processing apparatus and the method therefor of the present invention are provided to resolve the conventional shortcomings. According to the invention, watermark data that indicate additional information, such as copyright information, can be optimized in accordance with the contents of object data, and the optimized watermark data can be embedded.

**[00182]** Furthermore, according to the image processing apparatus of the invention and the method therefor, watermark data can be optimized in accordance with the quality of image data, such as the property of an object, so that watermark data that is less noticeable and is easily detectable can always be employed to perform embedding.

**[00183]** While the invention has been particularly shown and described with respect to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.